Section 5
Economic Analysis

This section presents cost estimates for using an anaerobic compost CWS system to treat mine drainage with water chemistry similar to the Burleigh Tunnel. The baseline scenario used for developing this cost estimate was a 50 gpm flowrate, the total flow from the Burleigh Tunnel, and a 15-year system life. The baseline costs were then adjusted for flowrates of 25 gpm and 100 gpm to develop cost estimates for other cases.

Cost estimates presented in this section are based primarily on data compiled during the SITE demonstration at the Burleigh Tunnel (CDPHE 1995). Additional cost data were obtained from standard engineering cost reference manuals (Means 1992). Costs have been assigned to 11 categories applicable to typical cleanup activities at Superfund and RCRA sites (Evans 1990). Costs are presented in year 1995 dollars and are considered estimates, with an accuracy of plus 50 percent and minus 30 percent.

5.1 Basis of Economic Analysis

A number of factors affect the costs of treating mine drainage with an anaerobic compost CWS system. These factors generally include flow rate, type and concentration of contaminants, physical site conditions, geographical site location, and treatment goals. The characteristics of spent substrate produced by a CWS system will also affect disposal costs. Spent substrate will require off-site disposal. Mine drainage containing cadmium at 0.05 parts per million (ppm), iron at 50 ppm, nickel at 0.5 ppm, and zinc at 50 ppm was selected for this economic analysis. The following presents additional assumptions and conditions as they apply to each case.

For each case, this analysis assumes that an upflow CWS system will treat contaminated mine drainage continuously, 24 hours per day, 7 days per week. An average metals removal efficiency of 96 percent was assumed for all cases. Based on these assumptions, the CWS system will treat about 26.3 million gallons of water per year of operation at the baseline flowrate of 50 gpm.

- Further assumptions about constructed wetlands treatment for each case include the following:
- A residence time of 75 to 150 hours is recommended for adequate metals removal.
- A porosity of 50 percent is assumed for the substrate material.
- Two baseline wetlands, size of 90 feet by 90 feet by 4 feet (2,300 cubic yards [yd^3]), will provide a 78 hour residence time at a flowrate of 50 gpm (wetland size is directly proportional to flowrate). Square wetlands were used for the cost estimation; however, other shapes may be preferable.
- Substrate material will require removal and replacement once every 5 years.
- The spent substrate is not a RCRA hazardous waste: thus, it will be dewatered on site and can be recycled or disposed of at an industrial landfill.
- An aerobic polishing pond to increase displaced oxygen is not required.

This analysis assumes that aquatic-based standards are most appropriate; and the attainment of these standards depends on the affected organisms, receiving waters and volume of mine drainage. Attainment may not be feasible in all cases for the technology as tested during this demonstration.

The following assumptions were also made for each case in this analysis:

- The site is located within 200 miles of the disposal location.
- The site is located within 100 miles of a moderate-sized city.

- The site will allow for gravity flow of the mine drainage through the wetland.
- A staging area is available for dewatering spent substrate.
- Access roads exist at the site.
- Utilities, such as electricity and telephone lines, are available on site.
- The treatment goal for the site will be to reduce zinc contaminant levels by 90 percent.
- Spent substrate will be dewatered and disposed of off site.
- One influent water sample and two effluent water samples will be collected monthly and two composite substrate samples will be collected quarterly to monitor system performance.
- One part-time operator will be required to inspect the system, collect all required samples, and conduct minor maintenance and repairs.

5.2 Cost Categories

Cost data associated with the CWS technology have been assigned to one of the following 11 categories: (1) site preparation; (2) permitting and regulatory requirements; (3) capital equipment and construction; (4) startup; (5) labor; (6) consumables and supplies; (7) utilities; (8) residual and waste shipping and handling; (9) analytical services; (10) maintenance and modifications; and (11) demobilization. Costs associated with each category are presented in the sections that follow. Some sections end with a summary of significant costs within the category. Table 9 presents the cost breakdown for the flow variant cases. This table also presents total one-time, fixed costs, and total variable O&M costs; the total project costs; and the costs per gallon of water treated.

5.2.1 Site Preparation Costs

Site preparation includes administration, pilot-scale testing, mobilization costs. This analysis assumes a total area of about 65 acres will be needed to accommodate the wetland and staging area, construction equipment, and sampling and maintenance equipment storage areas. A solid gravel (or ground) surface is preferred for any remote treatment project. Pavement is not necessary, but the surface must be able to support construction equipment. This analysis assumes adequate surface areas exist at the site and that only moderate modifications will be required for wetland construction.

Administrative costs, such as legal searches and access rights, are estimated to be an additional $10,000.

Mobilization involves transporting all construction equipment and materials to the site. For this analysis, it is assumed that the site is located within 100 miles of a city where construction equipment is available. The total estimated mobilization cost will be $5,000.

For each case, total site preparation costs are estimated to be $15,000.

5.2.2 Permitting and Regulatory Requirements

Permitting and regulatory costs vary depending on whether treatment occurs at a Superfund site and on the disposal method selected for treated effluent and any solid wastes generated. At Superfund sites, remedial actions must be consistent with ARARs, environmental laws, ordinances, and regulations, including federal, state, and local standards and criteria. In general, ARARs must be identified on a site-specific basis. At an active mining site, a NPDES permit will likely be required and may require additional monitoring records and sampling protocols, which can increase permitting and regulatory costs. For this analysis, total permitting and regulatory costs are estimated to be $5,000.

5.2.3 Capital Equipment

Capital costs include all wetland construction and construction materials and a site building for housing sampling, monitoring, and maintenance equipment. Construction materials include sand, synthetic liners, geotextile liners, PVC piping, valves, concrete vaults or sumps, weirs, and other miscellaneous materials. Capital costs for the baseline wetland of 50 gpm are presented below. Site preparation and excavation include clearing the site of brush and trees, excavation of the wetland cell, grading the cell, and construction of the earthen berms. The total cost of site preparation and excavation is $19,500 for the 50 gpm system.

Construction of the wetland cell itself involves system design, subgrade preparation and installation of a sand layer, liner, piping distribution and collection systems, and the substrate. Also included is piping to and from the cell as well as system bypass piping, and concrete sumps with weirs at the influent of the wetland to control flow through

Table 9. CWS Costs for Different Treatment Flow Rates*

Cost Categories	System Life 15 Years					
	25 gpm		50 gpm		100 gpm	
Fixed Costs						
Site Preparation	$15,000		$15,000		$15,000	
Administrative		$10,000		$10,000		$10,000
Mobilization		5,000		5,000		5,000
Permitting and Regulatory Requirements	$5,000		$5,000		$5,000	
Capital Equipment	$215,300		$345,000		$604,500	
System Design		$50,000		$50,000		$50,000
Excavation and Site Preparation		9,800		19,500		39,000
Wetland Cell Construction		120,000		240,000		480,000
Piping and Valves		25,500		25,500		25,500
Storage Building		10,000		10,000		10,000
Startup	$1,500		$1,500		$1,500	
Demobilization	$52,250		$104,500		$209,000	
Excavation and Backfilling		$10,000		$20,000		$40,000
Substrate Disposal		42,250		84,500		169,000
Total Fixed Costs	$316,000		$492,000		$844,000	
Variable Costs						
Labor	$153,000		$153,000		$153,000	
Operations Staff		$153,000		$153,000		$153,000
Consumables and Supplies	$39,000		$39,000		$39,000	
Personal Protective Equipment		$39,000		$39,000		$39,000
Utilities	NA		NA		NA	
Residual and Waste Shipping and Handling	$120,000		$240,000		$480,000	
Substrate Disposal		40,000 (3)		80,000 (3)		160,000 (3)
Analytical Services	$360,000		$360,000		$360,000	
Maintenance and Modifications	$247,550		$490,100		$975,200	
Annual Maintenance		$5,000		$5,000		$5,000
Substrate Removal and Replacement		80,850 (3)		161,700 (3)		323,400 (3)
Total Variable Costs	$919,550		$1,282,100		$2,007,200	
Total Costs	$1,235,500		$1,774,100		$2,851,200	
Total Cost Per Gallon Treated	$0.0063		$0.0045		$0.0036	

*Costs are based on July 1995 dollars, rounded to the nearest $100.
Substrate removal and replacement estimated to be necessary every 5 years.
(3) Number of removals anticipated
NA Not applicable

the system. The total cost for wetland cell construction of a 50 gpm system is $335.000.

A small building is required for storing sampling equipment and providing work space for the system operator. The cost for a simple building with electricity has been estimated at $10,000.

The total capital cost for a 50 gpm wetland system is $345,000.

5.2.4 Startup

Startup requirements are minimal for a wetland system. System startup involves introducing flow to the wetland with frequent inspections to verify proper hydraulic operation. Operators are assumed to be trained in health and safety procedures. Therefore, training costs are not incurred as a direct startup cost. The only costs directly related to system startup are labor costs associated with more frequent system inspection. Startup costs are estimated at $1,500.

5.2.5 Labor

Labor costs include a part-time technician to sample, operate, and maintain the system. Once the system is functioning, it is assumed to operate continuously at the design flow rate. One technician will monitor the system on a weekly basis. Weekly monitoring will require several hours 2 to 3 times per week to check flowrate and overall system operation. Sampling is assumed to be conducted once a month and will require two technicians for 2 hours. These requirements equate to 175 hours annually for general O&M. An additional 80 hours of labor are included for miscellaneous O&M and review of data. Based on $40 per hour for a technician, the annual cost for general labor O&M is $10,200.

5.2.6 Consumables and Supplies

The only consumables and supplies used during wetland operations are disposable PPE. Disposable PPE includes Tyvek coveralls, gloves, and bootcovers. The treatment system operator will wear PPE when required by health and safety plans during system operation. PPE will cost about $25 per day per person on site. Based on the assumed labor required above and an additional 22 days for miscellaneous O&M, PPE will be required 100 days annually, for an annual PPE cost of about $2,500.

5.2.7 Utilities

Utilities used by the wetland system are negligible. The wetland system requires no utilities for operation. The only utility required is for electricity for lights in the on-site storage building and for charging monitoring equipment. For this analysis, utility costs are assumed to be zero.

5.2.8 Residual Waste Shipping and Handling

The residual waste for the wetland is assumed to be spent substrate. This analysis assumes that substrate will require removal and replacement once every 5 years. It is assumed that spent substrate will be dewatered on site and disposed of at a recycler or landfill. Substrate removal and replacement costs are covered in Section 5.2.11, maintenance and modifications. Loading dewatered substrate into 20 yd^3 haul trucks is estimated to cost $14,500. Hauling the substrate to a recycler or landfill is estimated to cost $28,000; disposal of substrate at the landfill costs $42,000. Oversight of substrate removal, hauling and replacement is expected to cost $3,200 (10 8-hour days at $40/hr). Loading of the new substrate is expected to cost $12,000 and the cost of the substrate is $65,200. The total waste shipping and handling cost per substrate replacement is $161,700. Costs for residual waste shipping and handling are based solely on substrate volume. Costs for different sized wetlands are proportional to the 50 gpm baseline system described here.

5.2.9 Analytical Services

Analytical costs associated with a wetlands system include laboratory analysis, data reduction and tabulation, QA/QC, and reporting. For each case, this analysis assumes that one influent sample and two effluent samples will be collected once a month and that two substrate samples will be collected quarterly. The substrate samples will be analyzed for total metals. Influent and effluent samples will be analyzed for total metals, ammonia, nitrate, phosphate, BOD, TSS, and TDS. Monthly laboratory analysis will cost about $1,050, and substrate analysis $3,500 per year. Data reduction, tabulation, QA/QC, and reporting are estimated to cost about $660 per month. Total annual analytical services for each case are estimated to cost about $24,000 per year.

5.2.10 Maintenance and Modifications

Annual repair and maintenance costs are expected to be minimal and for this analysis are assumed to be $5,000 for each case. No modification costs are assumed to be incurred. The major maintenance cost will be removal and replacement of the substrate every 5 years. Excavation of substrate material has been estimated to cost $14,500 for the 50 gpm scenario. Replacement of the distribution and collection piping was estimated to cost $14,300. Purchase and transport of new substrate was estimated to cost $65,400. The total estimated cost of substrate removal and replacement is $161,700. The removal and replacement cost will vary proportionally with the wetland size.

5.2.11 Demobilization

Site demobilization costs include excavation of the substrate and concrete vaults and weirs, disposal of substrate, and backfilling the wetland. For the 50 gpm scenario, excavation costs are estimated at $10,000. Substrate disposal costs are $80,000. Backfilling of the wetland is expected to cost $10,000, assuming native material from the original wetland excavation was left on site. The total demobilization cost is estimated to be $104,500. This cost will vary proportionally with wetland size.

Section 6
Technology Status

Currently, several hundred constructed and natural wetlands are treating coal mine drainage in the eastern United States. The effectiveness of these systems is discussed in several publications including Hammer 1989, Moshiri 1993, and the proceedings of annual meetings of the American Society for Surface Mining and Reclamation, and several U.S. Bureau of Mines papers (U.S. Bureau of Mines Special Publication SP066-4 and Information Circular IC 9389) (see Appendix B).

In addition, any constructed wetlands designed to treat metal mine drainages have been constructed and tested or are being tested by EPA, various state agencies, and industry. In Colorado, the state Division of Minerals has constructed several wetland systems to treat metal mine drainage. Constructed wetlands treatment is also being considered for the full-scale remedy of the Burleigh Tunnel drainage.

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